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RESTRICTING DUST EMISSION IN BLAST-FURNACE OPERATION

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RESTRICTING DUST EMISSION IN BLAST-FURNACE OPERATION

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16. Abstracts

The purposes of these specifications are to: characterize the influenceswhich create dust; to point out measures for the reduction of dust emission; establish guide lines for permissible dust emission; determine the necessity for dust removal from flue gases and to give indications for the selection of suitable dust separators.

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Foreword

This is one of several dozen VDI Clean Air Committee specifications on air purification which the Division of Air Pollution of the U.S. Public Health Service has obtained permission to translate, publish, and distribute in limited quantity. A complete list of the VDI publications being published by the Division of Air Pollution appears on the inside back cover. Because the VDI Committee from time to time revises these specifications, this and other publications in the series may be superseded by later publications.

The VDI Clean Air Committee specifications are compiled by trade or professional associations and published by the Committee. The Committee has neither official status nor regulatory authority, although West German governmental agencies participate in its activities. Air quality specifications published by the Committee are therefore advisory, rather than regulatory. They may however later be adopted by West German governmental authorities.

The English translations were done by the Joint Publications Research Service of the Office of Technical Services, U.S. Department of Commerce. It should be borne in mind that various terms literally taken from the German do not have the same connotation in English; for example, the word "standard" frequently appears where the word "criteria" might better reflect the comparable American meaning, since in this country "standard" is generally meant to imply a legally enforceable value, while "criteria" usually means a recommended value upon which standards may be based.

The publication and distribution of these translations by the Public Health Service constitutes neither endorsement of the specifications nor of the air quality or emission limitations recommended in them. We believe that they contain much useful information that would otherwise not be available to non-readers of German and for this reason have made them available to workers in the air pollution field in the United States.

RESTRICTING DUST EMISSION IN BLAST-FURNACE OPERATION

Prepared by:

Society of German Metallurgists, Düsseldorf

VDI No. 2099, February 1959

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NOTES ON SPECIFICATIONS ON "DUST EMISSION"

The VDI Committee on Air Purification has assumed the task of determining the sources of air pollution, of collecting technical documentation and of preparing suggestions for improvement of conditions. The Committee is composed of experts in all fields of importance for safeguarding the purity of the air.

The findings obtained are utilized for the preparation of "Specifications" in which the measures for improving air purification are grouped together.

The specifications are subdivided into the following groups:

1) Guide lines for the calculation of distribution;
2) Guide lines for permissible immission concentrations;
3) Guide lines on restricting dust and gas emission;
4) Guide lines on measuring techniques.

A review of all known sources of air pollution is contained in VDI Specifications No. 2090.

The committee will adapt the catalogue on sources and the guide lines progressively to the latest scientific and technical findings. The catalogue, the guide lines and other technical documentation of the VDI Committee on Air Purification are collected in the VDI Manual on Air Purification.

FOREWORD

It is the task of the specifications on "dust emission":

1) to characterize the influences which create dust;
2) to point out measures for the reduction of dust emission;
3) to establish guide lines for permissible dust emission;
4) to determine the necessity for dust removal from flue gases and to give indications for the selection of suitable dust separators.

- Knowledge of the relation between emission and deposition is important for an objective evaluation of the dust level. Present research findings give many indications on this relation (1-4) but the evaluation of given circumstances is made very difficult by multiple factors.

Only accurate and comparable measurements provide reliable data for correct evaluation. Measurements must be carried out by experts according to the VDI Specifications on Efficiency Tests for Dust Separators (5).

The determination of the permissible emission from an installation depends to a large extent on the conditions in the area and can therefore be effected only on the basis of measurements which take into account also prior existing load factors.

These specifications are applicable only to newly designed installations.

Gaseous emissions including sulphur dioxide are treated in the specifications on "Gas Emission".

1. Technology

1.1 The Blast-Furnace:

The blast furnace (Fig. 1) is a shaft furnace for the production of pig iron. The burden consists of iron ore (+ 25% Fe) and the complete charge of lime stone (for slag formation) and generally also of sinter (Cf. VDI No. 2095) and scrap together with coke. Coke undergoes combustion by induced draft (550-900° C) to blast-furnace gas containing carbon monoxide. Coke and blast-furnace gas reduce the iron ore which is smelted into pig iron at temperatures between 1,500 and 1,800° C. The gangue of the ore (primarily lime, silicic acid and alumina) is transformed to slag of the same time. A modern blast furnace, 30 m high and with a hearth diameter of 8 m, reaches an output of over 1,000 ton/day of pig iron. During 1957, 18.4 million tons of pig iron were produced in Western Germany.

The processes in the blast furnace include numerous complicated physicochemical and metallurgical reactions which are quite difficult to observe and supervise, especially in the lower zones of high temperature (up to 1,900° C), so that the reduction and smelting process is not even today fully known in all its details.

1.2 Operating Data for Blast Furnaces:

1. Furnace		
1.1 Utilization		Production of pig iron
1.2 Burden and charge		Iron ore, coke, lime stone, sinter, scrap.
1.3 Capacity	ton/day	60-1,200 and over
1.4 Specific furnace load	kg coke/ $m^2 \cdot h$	600-1,200
1.5 Coke consumption	kg/ton iron	700-1,200
1.6 Heat consumption of blast-furnace process	10^6 kcal/ ton coke	3.2-3.8
1.7 Blast-furnace temperatures	°C	1,700 at hearth (molten iron); to 200 at throat

(continued)

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2. Blast-furnace gas factors (raw gas)		
2.1 Volume produced	Nm^3/t coke	3,900 average
2.2 Chemical composition		Cf. Table 1
2.3 Temperature at throat	°C	100-300
2.4 Dew point	°C	35-50
2.5 Calorific value	kcal/Nm^3	750-1,100
2.6 Properties (purified gas)		Cf. Table 2 and 3
3. Flue dust		
3.1 Volume of dust	% of iron	2-20
3.2 Raw-gas dust content	g/Nm^3	10-50 (up to 200 in special cases)
3.3 Chemical composition		Cf. Table 4
3.4 Grain classification		Cf. Figs. 3 and 4 and Table 5
4. Dust removal		
4.1 Type of separator		Cf. Sec. 2.1 and 2.2
4.2 Efficiency rate		
4.3 Dust separation		

1.3 Blast Furnace Gas:

Blast-furnace gas has a high content of dust and is made poisonous by the carbon monoxide contained in it (Table 1). It therefore needs to be purified before being used as fuel gas (Table 2). The heat and power economy of iron smelters is based on this valuable by-product. The modern blast furnace is completely closed so that the entire volume of gas is recovered at the throat. An extensive system of pipe lines, sometimes many kilometers long, transports the gas to the individual consumer (Fig. 2).

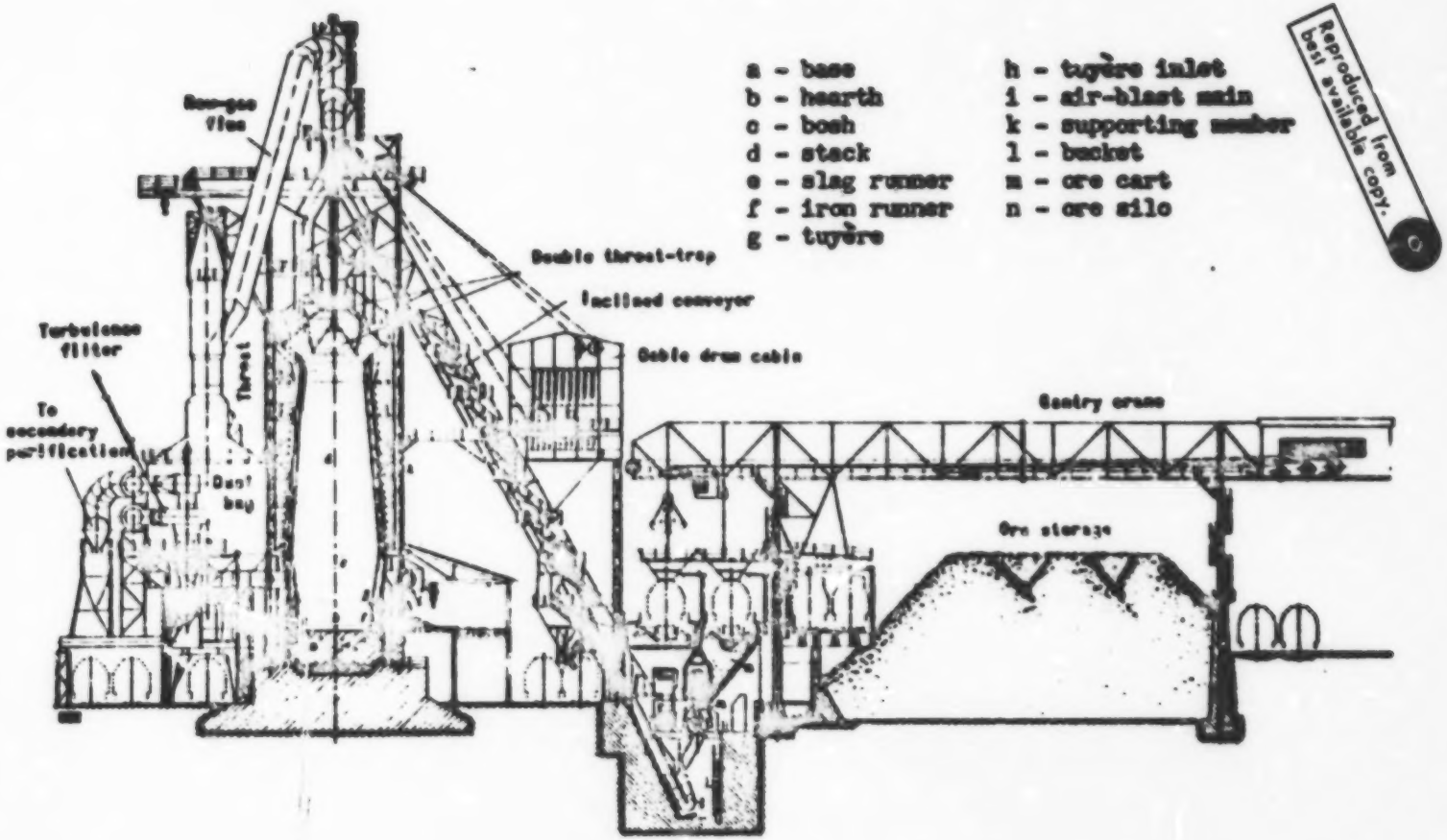

Figure 1. Modern-Blast Furnace Installation for Pig Iron Production of 1,200 ton/24 hr (Steel and Iron, Vol. 74, 1954, p. 1459)

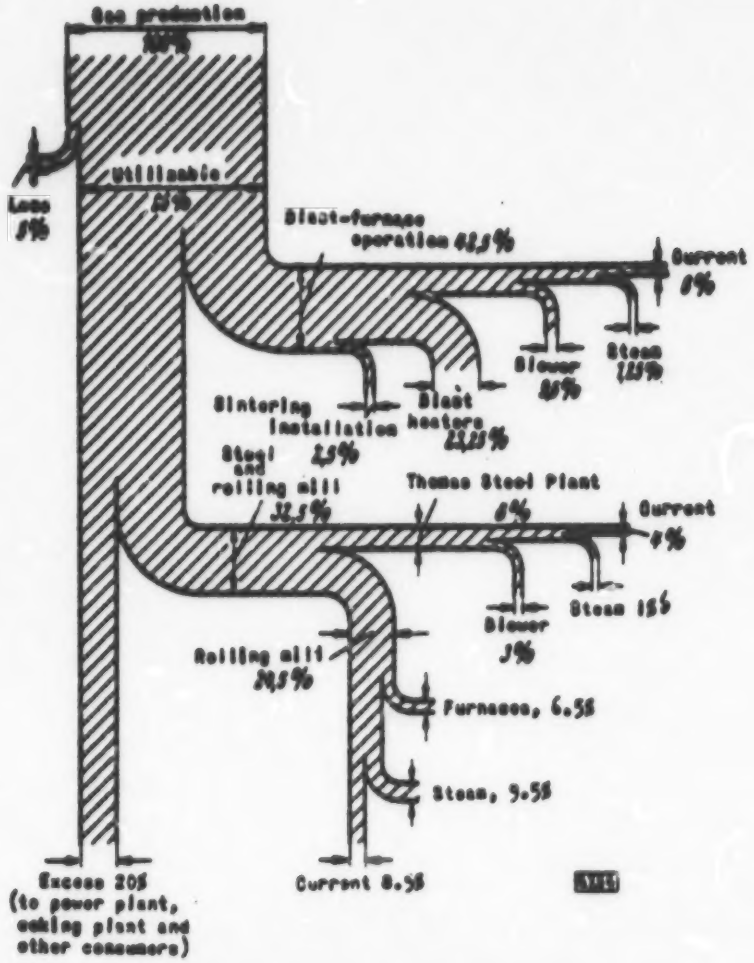

Figure 2. Blast-Furnace Gas Distribution of Combined Iron Smelter and Steel Plant.

Blast-furnace gas is used for heating of the blast air (Cowper), of the smelting and annealing furnaces of the steel and rolling mills and the press and forging units, in particular also for firing thermal power plants, as fuel in internal-combustion engines and gas turbines, for firing coke ovens, etc. (Table 3). After combustion of carbon monoxide and hydrogen, the spent blast-furnace gas is discharged into the atmosphere (Cf. Sec. 2.7).

Table 1

CHEMICAL COMPOSITION AND CHARACTERISTICS OF NON-PURIFIED BLAST FURNACE GAS

CO_2	10-16 Vol.-%
CO	25-30
H_2	0.5-4
CH_4	0.2-3
N_2	50-60
S, H_2S, SO_2, O_2	only traces
H_2O	50-60 g/Nm^3
Dust content	10-50 g/Nm^3
Specific unit weights of purified gas (at about 9% CO_2)	About 1.3 kg/Nm^3

In the blast furnace process, about 4,000 Nm^3 of blast-furnace gas are produced per ton of pig iron. An average-size blast furnace furnishes 3 x 10^6 Nm^3/day of blast-furnace gas, together with 50-80 ton/day of flue dust. As by-product of iron smelting, blast furnaces in West Germany during 1957 produced almost 7 x 10^{10} Nm^3 of blast furnace gas which was purified from dust and utilized as fuel.

Table 2

CHARACTERISTIC OF BLAST FURNACE GAS USED AS ENGINE FUEL

H_2O	15-35 g/Nm^3
Dust content	20 mg/Nm^3
Calorific value	about 1,000 kcal/Nm^3
Combustion air ratio	$\leq$ 0.9-1.2

Chemical composition and specific unit weights (Table 1) do not change during purification.

Table 3

CHEMICAL COMPOSITION OF WASTE GAS FROM FURNACE INSTALLATIONS FIRED WITH BLAST-FURNACE GAS

CO_2	20-25 Vol.-%
N_2	70-75
SO_2	$\leq$ 8 mg/Nm^3
CO, H_2, O_2	traces
Dust content	20-50 mg/Nm^3 depending on dust content of combustion air.

1.4 Blast-Furnace Flue Dust:

The dust in blast-furnace gas is entrained partially out of the charge and partially enters into the blast-furnace gas with the sublimation of vaporized slag and metal. Chemical composition, volume and classification of flue dust are largely dependent on the physical and chemical characteristics of the blast-furnace charge. Chemical composition and classification also change with distance from the blast furnace through sedimentation in the gas lines and precipitation in the dust-removal installations.

The volume of flue dust per ton of pig iron amounts to about 20-200 kg or 2-20% of pig iron production. In low grade non-sintered iron ores, these values may rise more than twice as high. On the average, the dust content lies between 10 and 50 g/Nm^3 but may attain 200 g/Nm^3 in defective furnaces.

The coarse iron-containing dust may have grain sizes up to several millimeters (defective furnaces may discharge pieces larger than a fist) and is precipitated in major part already in the primary mechanical dust-removal devices (dust bag, turbulence filter). The precipitation of the fine dust containing little iron, especially of the small grain sizes from < 0.01 to 2μ requires high-efficiency dust separators.

Table 4

GRAIN SHARE $> 60\ \mu$ IN BLAST FURNACE GAS

Raw gas	75 - 97%
Precipitation in primary separator	85 - 92%
Precipitation in secondary separator	< 10%
Purified gas	< 5%

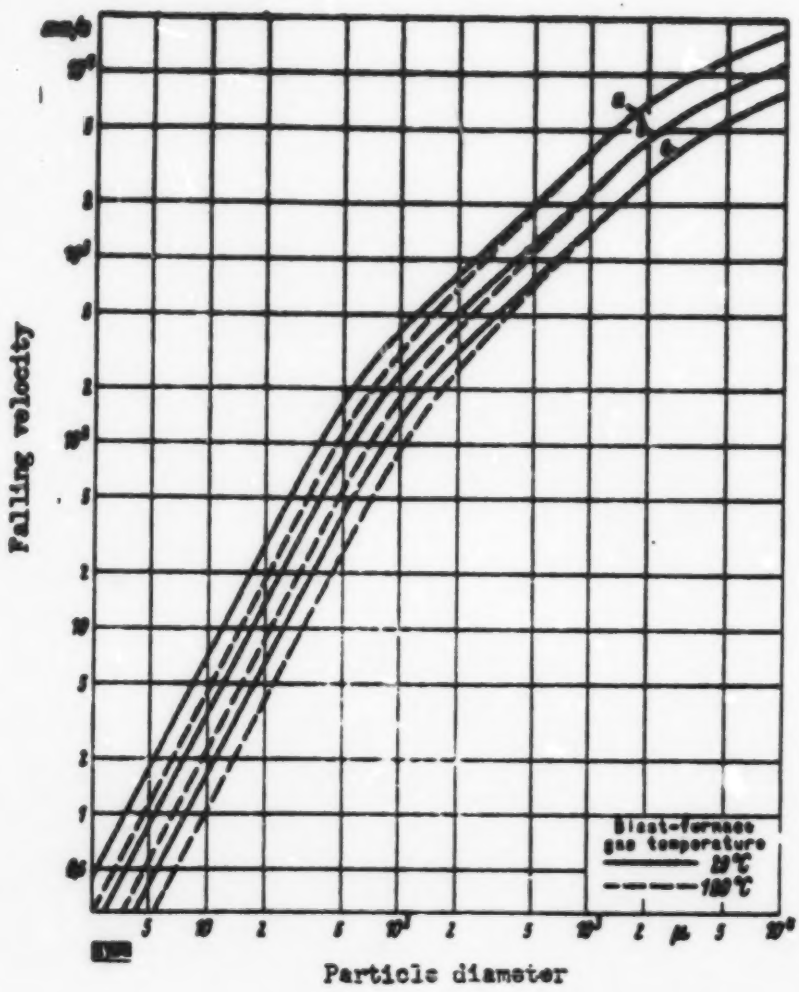

Figure 3. Falling Velocity of Various Particles of Blast-Furnace Charge as a Function of Particle Diameter at 20 and 180° C (from American investigations).

a - ore dust; b - lime dust; c - coke.

Specific weight (g/cm^3)	5.2	2.3	1.2

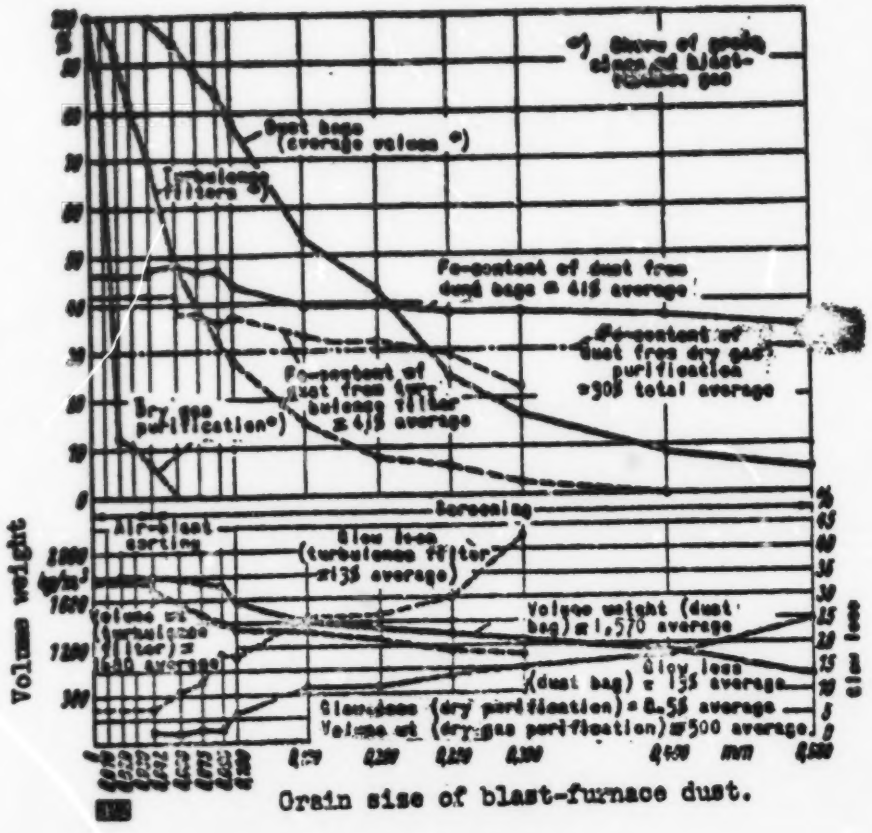
Dust bags (average values *)
Turbulence filters *)
Fe-content of dust from dust bags = 41% average
Fe-content of dust from dry gas purification = 30% total average
Fe-content of dust from turbulence filter = 41% average
Dry gas purification *)
Screening
Air-blast sorting
Sieve loss (turbulence filter = 13% average)
Volume weight (dust bag) = 1,570 average
Sieve loss (dust bag) = 13% average
Sieveloss (dry purification) = 8.5% average
Volume wt (dry-gas purification) = 500 average
Volume weight
Grain size of blast-furnace dust.

Figure 4. Data on Blast-Furnace Gas Dust (dust discharged from dust bag, turbulence filter, dry-gas purification) from C. Popp, Steel and Iron Vol. 58, pp. 224/231.

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Table 5

CHEMICAL COMPOSITION OF BLAST FURNACE FLUE DUST

Substance	% Wt.	Substance	%-Wt.
Fe	5 - 40	S	To 0.1
SiO_2	9 - 30	C	5 - 10
CaO	7 - 28	Zn	0 - 35
MgO	1 - 5	Pb	0 - 15
Al_2O_3	4 - 15	Alkali	0 - 20
Mn	0.3 - 1.5	Cu	traces
P	0.3 - 1.2		

2. Reduction of Dust Emission

2.1 Selection of Dust-Removal Installation for Blast-Furnace Gas Purification

The utilization of blast-furnace gas for the operation of gas engines and turbines requires careful purification which is carried out in a primary and a secondary stage. The secondary stage requires preceding cooling and the coolers act simultaneously as additional purifiers (Sec. 2.2).

Coarse Purification:

This is done by means of dust chambers (so-called dust bags) and frequently also with subsequent turbulence filters (Cf. Fig. 1) which remove dust at efficiency rates of 50 to 80% from the blast-furnace gas with a residue of 5-10 g/Nm^3 (even less with combined dust separators).

Gas Coolers:

In addition to their main purpose of cooling the gas after it leaves the primary dust separators, the coolers also have an additional purification action. At efficiency rates of 30 to 90%, the dust content of the pre-purified gas is lowered to 1-5 g/Nm^3. The less effective

spray coolers are generally arranged ahead of bag filters and hurdle filters, scrubbing towers, jet coolers, and simplified Venturi standpipe scrubbers are placed ahead of disintegrators and wet electrostatic precipitators.

Secondary Purification:

For secondary purification, only bag filters, wet scrubbers (such as disintegrators and in the USA frequently also Pease-Anthony Venturi-scrubbers) and wet electrostatic precipitators are suitable. All of them require pre-cooling and the bag filters operating at higher temperature also secondary cooling in order to prevent condensation of moisture in the gas lines. The efficiency rate of these installations is over 99% and residual dust remains at 5-15 mg/Nm^3.

Total Purification Installation:

During the several stages of the purification process, the following shares of dust are precipitated from the gas:

Primary purification	70-80%
Pre-cooling	10-20%
Secondary purification	3-10%

The total purification installation lowers the dust content of the blast-furnace gas from 10-50 g/Nm^3 to 5-15 mg/Nm^3 which corresponds to an efficiency rate of over 99.9%.

2.2 Operating Data of Customary Dust Separators (3 to 7):

The following indicates average values for properly maintained dust separators:

Type of Separator	Efficiency Rate %	Dust Content Raw Gas g/Nm^3	Dust Content Pur. gas g/Nm^3	Pressure Drop* mm water	Utilization
1 Dry Process					
1.1 Dust chambers (dust bags)	50-80	10-50	5-10	15-40	Primary purification of non-cooled gas with high dust content.
1.2 Turbulence filters	50-80	5-10	5	30+	Primary purification of non-cooled gas with low dust content.
1.3 Bag filter (type Halberg-Beth)	99+	1-5	0.005-0.015	150-300	Secondary purification of pre-cooled gas (70-90° C).
2. Wet Process					
2.1 Pre-cooler (spray)	30-50	5-10	1-5	20-50	Purification and cooling to 70-90° C.
2.2 Hurdle filters, scrubbing towers, jet coolers	50-90	5-10	0.7-2.0	50-200	Purification and cooling to about 25° C.
2.3 Disintegrators	99+	0.7-2.0	0.005-0.015	50-100**	Residual dust 1-2 g/Nm^3 and gas temperature 25° C.
2.4 Wet electrostatic precipitators	99+	0.7-2.0	0.005-0.015	5-10	

* Pressure of blast-furnace gas at throat outlet 150-1,000 mm water.
** Generally as pressure rise of about 50-100 mm water.

2.3 Pointers for Cloth Filters:

Effect on efficiency rate of dust separators is:	
Unfavorable	Favorable
Excessive filter load due to excessive gas or dust volumes.	Proper selection of filter cloth corresponding to type of dust, gas temperature and composition.
Non-uniform gas distribution.	
Excessive temperatures. Unsuitable types of cloth. Defective cloths.	
Temperature drop below dew point.	Proper maintainance of filter and continuous control of filter insulation.
Poor cleaning of filter cloths.	Proper dust suction devices.

2.4 Pointers for Mechanical Dust Separators (Bag and/or turbulence filters):

Effect on efficiency rate of dust separators is:	
Unfavorable	Favorable
High share of fine dust.	Dust separators for special cases.
Non-uniform loading of several parallel cyclones.	Uniform distribution among several parallel aggregates and proper aerodynamic design of gas lines.
Partial or overload operation of non-adjustable dust separator. Incorrect adjustment of load of adjustable separator.	Shut-down of units not needed under partial load.
Internal leakage due to wear; by-passes between single or multi-cyclones or cell dust separators.	Proper maintainance and frequent control of parts subject to wear and protection by appropriate lining.

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Effect on efficiency rate of dust separators is:	
Unfavorable	Favorable
Clogging, in particular of cells and dust discharges of cells and single cyclones. Leaking valves and traps, in particular of dust suction devices.	Prevention of temperature drop below dew point. Current recording of measurable operating data, e.g., pressure drop and energy consumption (changes in value generally indicate defects and errors).
Incorrectly dimensioned separators (the efficiency rate depends on the volume of gas throughput)	Correctly dimensioned separator for normal load of blast furnace and discharge of collected dust at proper time.

2.5 Pointers for Wet Electrostatic Precipitators:

Effect on efficiency rate of separator is:	
Unfavorable	Favorable
Operational deviations from design data of separator, e.g., of volume and velocity of gas (extraneous air, overload), dust content and grain classification of raw gas.	Gas velocity too low and time of passage through separator too long.
Dust with varying electrical resistance due to changes in charge (iron ore, sinter, etc.)	Optimum purification is attained at 20-25° C and saturated gas.
Unsuitable voltage (frequent sparking, short circuits or switch-opening). Inappropriate deposition or spray electrodes.	Highest possible voltage through full-automatic voltage regulation. Gas flow most favorable for the respective type of dust and corresponding phasing of electrode voltage in the individual chambers (pre-ionization).

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Effect on efficiency rate of dust separator is:	
Unfavorable	Favorable
Non-uniform gas and dust inflow. Aerodynamically unfavorable construction members in dust chamber (dust deposition on girder, etc.). Non-uniform distribution of dust in gas flow. Inappropriate cleaning of electrodes (spray water).	Uniform velocity and distribution of dust over entire cross section of separator and guide vanes or perforated plates to improve inflow. Prevention of dust deposition at angles in guide vanes and at electrodes.
	Proper operation and maintainance of separator cleaning devices (spray devices) through inspection of electrodes, cleaning of separator interior with chamber shut down when necessary.
	Regular or automatic slurry removal; properly sealed and proper control and maintainance of slurry-discharge devices; prevention of extraneous-air admission also at non-sealed valves (e.g. for bypass lines).
Poor control and maintainance of the overall installation.	Systematic inspection of the most important units and regular control of efficiency rate; properly scheduled overhaul; current recording of measurable operating data (changes in value generally indicate defects and errors).

2.6 Measure in Special Cases:

The dust clouds occasionally visible at the throat of the blast furnace during operational failures occur only occasionally and briefly as well as almost exclusively only in the immediate vicinity of the blast furnace. Purification of these dust clouds is not possible with any presently existing techniques.

At some blast-furnace installations, excess and not otherwise utilisable blast-furnace gas occurs due to several operational reasons, and must be burnt off, in particular during sudden operational failures. The "torch" required for this is an integral part of the design of the local gas-purification. In already existing installations, the possibility exists of liberating primary-purified gas through the "torch" with a dust content of 1-2 g/m³.

During starting or shut-down, the blast furnace must be disconnected from the gas lines and consequently also from the gas purification installation for safety reasons and blast-furnace gas must be burnt off directly from the blast furnace through the "torch" but these are exceptions of short duration.

2.7 Stacks:

The specifications on Restricting Dust Emission (Cf. Sec. 3) establish the height and number of stacks.

In addition to the creation of the necessary draft, the most essential task of the stack is to discharge gas and dust as far as possible from the surface of the ground and to effect simultaneously a reduction of the ground concentration of such discharges by a better distribution of the smoke streamer.

This should be attempted by:

a) stacks as high as possible;
b) velocity of gas at top of smoke stack as high as possible;
c) maximum possible utilisation of thermic lift of smoke streamer.

Cf. a) The lower limit of stack height is given by Sec. 3 of these specifications. In view of the immediate vicinity, experience indicates that the top of the stack should not be less than 1.7 times as high as the highest building in the immediate vicinity.

Cf. b) In compliance with Sec. 3 of the Specifications, the smoke discharge-velocity of waste gases with a high content of dust and/or gas should be as high as possible.

Cf. c) At the same waste-gas temperature, greater thermic lift is produced by a large-diameter stack -- due to the lesser cooling of a smaller surface -- than by distributing the same volume of flue gases over several stacks of smaller diameters. Discharge of flue gases of several pre-heating furnaces through a stack with a large diameter may

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be more advantageous than an arrangement of several stacks of small diameters. In determining the diameter of a stack, however, partial load factors must be taken into consideration.

3. Guide Lines for Restricting Dust Emission

The following factors should be taken into consideration in the design of new blast-furnace installations:

1) Restriction of Emission on the Basis of Dust Deposition:

The emission of dust of an installation should be restricted on the basis of the permissible amounts of deposition in the vicinity and by the conditions of distribution given by the type of construction and location of the plant (stack height, orographic position, adjacent emitters, etc.). The existing and permissible dust level of the area should be included therein. (Note: This manner of determining the restriction of emission by deposition takes into account the natural laws between emission, distribution and deposition. Details of the method should be based on the latest technical findings. The VDI Committee on Air Purification issues special instructions in this regard.)

2) Restriction of Emission on the Basis of Given Technical Factors

Especially in view of the further utilization of blast-furnace gas, provision should be made for a technically and economically defensible installation, corresponding to the type and capacity of the plant, for reducing the dust content of purified gas. The maximum permissible dust content for newly designed blast-furnace installations in continuous operation should not exceed 20 mg/Nm^3 of purified gas and 50 mg/m^3 of the flue gases of furnace installations and other consumers operated with blast-furnace gas. Accordingly, blast-furnace gas burnt off by "torch" should be purified in the same manner.

All newly designed blast-furnace installations should be equipped with dust-removal installations which should meet the data on restriction of emission established in Sec. 1, sub-section 2 unless Sec. 3, sub-section 1 provides for higher demands. Only such dust-removal installations should be built which correspond to the latest technical findings.

The maximum values resulting from Sec. 3, sub-section 2 assume that the raw-gas dust content specified in the order will not be exceeded and that the specified efficiency rates will be maintained so that the corresponding values should be guaranteed by the supplier.

In operation of the installation, individual tolerances for any given case should be included in the guaranty data. If acceptance inspection does not confirm the specified guaranty, the supplier is required to effect the necessary changes and alterations.

In individual cases where the requirements of Sec. 3, subsection 2 on restriction of emission cannot be complied with, due to particular operational conditions not to be anticipated in the design, exceptions can be authorized only if the dust removal installation was designed according to the latest technical findings.

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Further reference is made to VDI documentation on Air Purification.

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VDI No.	Title
2090	Sources of Air-Polluting Substances
2091	Restricting Dust Emission From Forced-Draft Boiler Installations, Capacity 10 Ton/Hr and Over, Hard-Coal Fired with Mechanical Grates
2092	Restricting Dust Emission From Forced-Draft Boiler Installations, Capacity 30 Ton/Hr and Over, Hard Coal-Dust Fired with Dry Ash Removal
2093	Restricting Dust Emission From Forced-Draft Boiler Installations, Capacity 30-600 Ton/Hr and Over, Hard Coal-Dust Fired with liquid Ash Removal
2094	Dust Prevention - Cement Industry
2095	Dust Emission From Induced-Draft Ore-Sintering Installations
2098	Restricting Dust Emission From Natural-Draft Steam Generators, Capacity 25 Ton/Hr and Less, Lignite-Fired with Stationary or Mechanical Grates
2099	Restricting Dust Emission in Blast-Furnace Operation
2101	Restricting Dust Emission From Copper-Ore Smelters
2102	Restricting Emission of Dust From Copper-Scrap Smelters
2103	The Restriction of Chlorine Gas Emission
2104	Terminology in Air Purification
2106	Permissible Immission Concentrations of Chlorine Gas
2107	Permissible Immission Concentrations of Hydrogen Sulphide
2108	Permissible Immission Concentrations of Sulfur Dioxide
2109	Restricting Emission of Hydrogen Sulphide and Other Sulphur-Containing Compounds, Except Sulphur Dioxide, From Gas Generators in Coke, Gas, and Coal-Constituent Processing Plants
2110	Restricting Emission of Sulphur Dioxide From Coke Ovens and Gas Plants
2115	Restricting Emission of Dust From Manually Operated Central-Heating Boilers, Capacity 600,000 KCAL/Hr and Less, Fired with Solid Fuels
2281	Restricting the Emission of Fumes From Diesel-Engine Vapors
2284	Restricting Emission of Dust and Sulphur Dioxide in Zinc Smelters
2285	Restricting Dust and Sulphur-Dioxide Emission From Lead Smelters
2290	Restricting Emission From Gas Generators in Coke and Gas Plants
2292	Restriction of Dust Emission in Anthracite-Briquet Factories
2293	Restricting Emission of Dust in Anthracite Processing Installations
2302	Restricting Emission of Dust, Tar Mist and Gas when Charging Coke Ovens
2105	Permissible Concentrations of Nitrous Gases

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